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Računalništvo in informatika

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Robotika

Razpoznavanje vzorcev - 3. letna konferenca SDRV

Biomedicinska tehnika

Močnostna elektrotehnika

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Slovenija

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# Using Recover-and-Select Paradigm on Triangulated Data \*

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## Abstract

*We introduce a new approach to segment triangulated data and to extract geometric models out of it. Recover-and-select paradigm successfully accomplishes these tasks when applied to range images. In this work we show that it can successfully be applied also to triangulated data. The key question here is the definition of the point's neighbourhood. This relation can easily be defined when dealing with triangulated data.*

## 1 Introduction

Recover-and-Select paradigm is used to recover different kinds of parametric models from images[3]. The paradigm has been concisely defined in an object-oriented form[2]. The main object of this paradigm is a description. The description consists of a set of points (so called region) and the parametric model. The model tries to approximate the points as accurately as possible. The criterion which shows how accurate the model is, is the average of distances of all the region points from the model. This criterion is called the model error. An ideal model would have the error equal to 0 but in general it is not possible to obtain such a model. The paradigm consists of three stages:

1. Placing seed descriptions,
2. Description growing,
3. Description selection.

To speed up the whole process stages 2 and 3 are performed several times. Stage 3 selects the most significant models with the MDL criterion and rejects the others in order to decrease the total number of models. As the final result the set of descriptions is obtained that try to approximate the image data.

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The rest of this paper is organized as follows: triangulated data and the neighbourhood relation are discussed in section 2, Recover-and-Select paradigm on triangulated data is described in section 3, followed by presentation of the experimental results and conclusion.

## 2 Triangulated data

The Recover-and-Select paradigm has been usually used in conjunction with range images on regular grid, which had a grid-like structure and the whole image could be defined as

$$z = f(x, y) \quad (1)$$

and if the input image has width  $w$  and height  $h$ , then  $1 \leq x \leq w$  and  $1 \leq y \leq h$ . The definition of neighbourhood relation between image points in this type of range images is straightforward — the points  $(x_i, y_i, z_i)$  and  $(x_j, y_j, z_j)$  are neighbouring points if and only if (2) is satisfied.

$$\max(|x_i - x_j|, |y_i - y_j|) = 1 \quad (2)$$

Triangulated data is mainly used to reduce the amount of the original input data. It consists of the  $(x, y, z)$  coordinates of each points and triangle definitions. The triangle definition consists of three integers denoting indices of points which form a single triangle. The neighbourhood relation for triangulated data is defined as follows: points with indices  $i$  and  $j$  ( $p_i$  and  $p_j$  respectively) are neighbouring if and only if there is a triangle in the data with integers  $i, j$  and  $k$  (the order of the integers doesn't matter), where  $k$  is an arbitrary point index (see Fig.1). As the neighbourhood relation is symmetric it holds that if  $p_i$  is the neighbour of  $p_j$  then also  $p_j$  is the neighbour of  $p_i$ . Triangulated data is suitable for visualization with the appropriate tools (e.g. Geomview) and for modeling free-form surfaces. As it still contains a lot of data, it is not suitable to be directly used for tasks like object recognition, reverse engineering, etc.

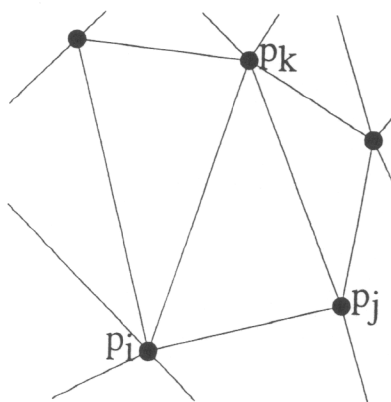


Figure 1: Triangulated data is defined by a set of triangles.

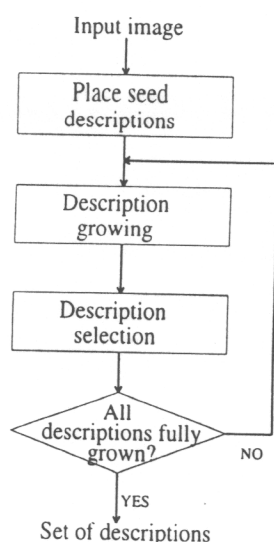


Figure 2: Stages in Recover-and-Select paradigm

### 3 Recover-and-Select paradigm on triangulated data

The Recover-and-Select paradigm on triangulated data consists of three stages: placing seed descriptions, description growing and description selection. The last two stages are interleaved until all descriptions are fully grown (see Fig. 2).

#### 3.1 Placing seed descriptions

This stage is almost trivial when dealing with range images on regular grid. Since range data is placed on the grid it is possible to choose rectangular regions that spread uniformly over the image. Seed size can be defined by its width and height. The model is then fit to the region points and the description is formed by the model and the corresponding region. The description is not accepted if its model error is too big.

In the case of triangulated data the situation gets slightly more complicated. Since in general there are no two points with the same  $x$  and  $y$  coordinate, it is not possible to place rectangular seed region on triangulated data. Thus we choose approach outlined in the following algorithm:

1. Let  $W$  be the set of all data points
2. **repeat**
3. Choose one point  $p$  from  $W$  and let  $R = \{p\}$
4. Let  $R_n$  be the neighbourhood region of  $R$
5. **while** number of points in  $R$  is less than seed\_size **and** number of points in  $R_n$  is greater than zero **do begin**
6. Let  $R = R \cup R_n$
7. Let  $R_n$  be the neighbourhood region of  $R$
8. **end while**
9. **if** number of points in  $R$  is greater or equal to seed\_size **then** fit the model to region  $R$
10. Let  $W = W \setminus R$
11. **until**  $W = \emptyset$

The neighbourhood of a region  $R$  is the set of points which do not belong to  $R$  and have at least one neighbour that belongs to  $R$ . Here again, when model is fit to the region, the description is not created if the model error is too big. The constant seed\_size determines the minimal number of points for a single seed description. The fact is that the seed regions are not created with the same number of points. This could cause some problems at the selection stage although we didn't notice any in our experiments. Probably a better way to place seed descriptions is to restrict the regions to have the same number of points.

#### 3.2 Description growing

One iteration of description growth is formed by the following steps:

1. let  $R_n$  be the neighbourhood of the description region
2. exclude from  $R_n$  all the points that are too distant from the description model
3. join all the points from  $R_n$  to description region
4. fit new description model to description region
5. **if** description model error is too big **then** retain the old description



The description stops growing when its error is too big or there is no points in its neighbourhood that are close enough to the description model.

Computation of the neighbourhood of the region was stated in the previous section. More detailed description of description growing based on range images can be found in [2, 3].

### 3.3 Description selection

Description growing requires a lot of computation time, especially if the number of descriptions is high. In order to speed up the whole process the number of descriptions is decreased from time to time by description selection based on MDL principle[3, 4, 5]. When many iterations of growth are applied to all descriptions, some of them become redundant. This means that their regions are almost completely overlapped by regions of other descriptions. We define an objective function [2]  $F(\mathbf{d})$  where  $\mathbf{d} = [d_1, d_2, \dots, d_n]$  and  $n$  is the number of descriptions that enter in the selection stage. The value of  $d_i$  is 1 if  $i$ -th description is already selected and 0 otherwise. From the optimal solution vector  $\mathbf{m}$ , which satisfies eq. 3, the selection process can determine which descriptions have to be destroyed.

$$F(\mathbf{m}) = \max_{\mathbf{d} \in \{0,1\}^n} F(\mathbf{d}) \quad (3)$$

To obtain the solution vector  $\mathbf{m}$  we use greedy algorithm. Description selection is performed after a few iterations of description growth. The process has to allow the description regions to grow enough, so that the selection can reject some redundant descriptions. More about description selection can be found in [2, 3, 1].

## 4 Experimental results

In this section we present the results obtained by recovering planes from triangulated data. After seed descriptions of size  $\geq 16$  have been placed on the data we performed 4 growing iterations and then executed the first selection. Then we increased growing iterations to 8 and performed the second selection. After each grow-select step the number of iterations was multiplied by two followed by the selection. It took from 4 to 6 such grow - select iterations to obtain the final results. The number of such iterations depends on the data and the models. The result of applying our approach on a sample image is shown in Fig. 3. Regions of different descriptions are colored by different gray levels. Our software is able to output the regions of descriptions in the OFF format, which can

be read and displayed by Geomview<sup>1</sup>. Geomview is a powerful tool and we produced images in Fig.3 by its camera snapshots.

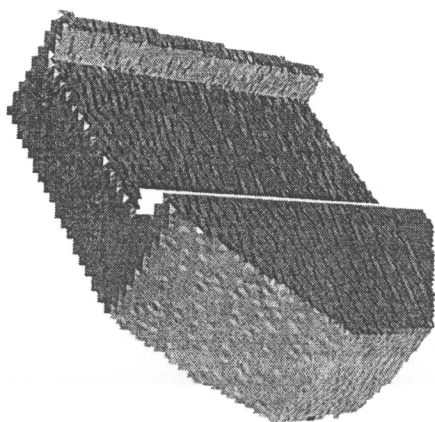
## 5 Conclusions

In this work we introduced another application of the Recover-and-Select paradigm. This paradigm can be used for any kind of images where the relation of neighbourhood between the image points can be established. In the future we will test our algorithm on a large set of images. Some work can also be done on recovering different types of models from triangulated data. The triangulated data we used for testing our program was collected from one camera view. In future we also plan to test our software with triangulated data collected from several views and merged for what we won't need to change absolutely nothing. The algorithm and the implementation would be the same, only visualization of the whole process would have to be adapted.

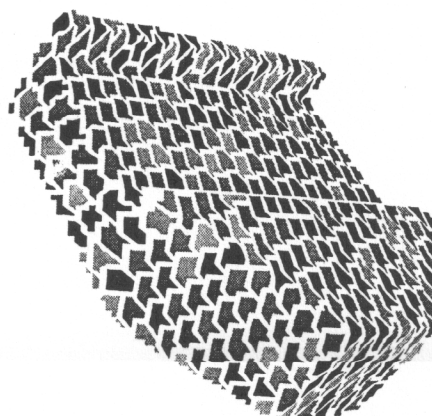
## References

- [1] A. Jaklič. Construction of CAD models from range images. *PhD dissertation*, Faculty for Computer and Information Science, University of Ljubljana, 1997.
- [2] A. Jaklič and A. Leonardis and F. Solina. Segmentor: An Object-Oriented Framework for Image Segmentation. *Proceedings of the 3rd Slovenian-German and the 2nd SDRV Workshop*, pp. 331-340, Ljubljana, Slovenia, 1996.
- [3] A. Leonardis and A. Gupta and R. Bajcsy. Segmentation of Range Images as the Search for Geometric Parametric Models. *International Journal of Computer Vision*, 14:253-277, 1995.
- [4] M. Kovačič and B. Kverh and F. Solina. Optimal models for Visual Recognition. *Theoretical foundations of Computer Vision*, Dagstuhl, 1996.
- [5] M. Pilu and R.B. Fisher, Recognition of geons by parametrically deformable contour models In R.Cipolla and B.Buxton, editors, *Fourth European Conference on Computer Vision*.

<sup>1</sup>Geomview is a visualization software package that has a lot of object manipulation options (scaling, shading, changing surface material, rotating, etc.) and can execute user written external modules. More information about Geomview is available via WWW on: <http://www.geom.umn.edu/software/geomview>.



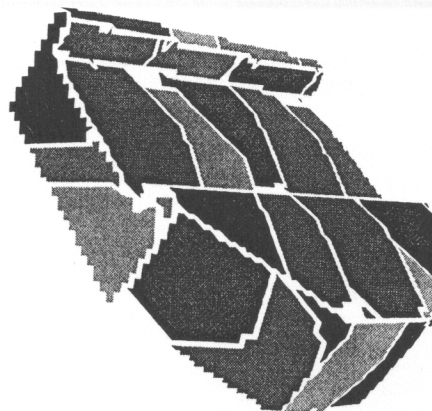
a)



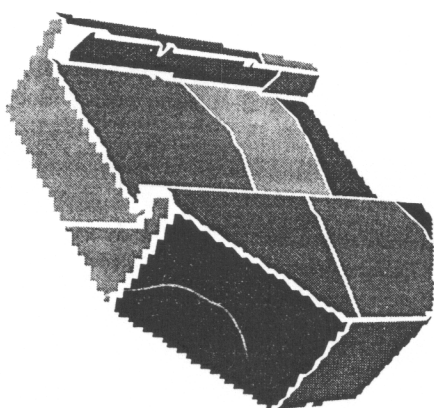
b)



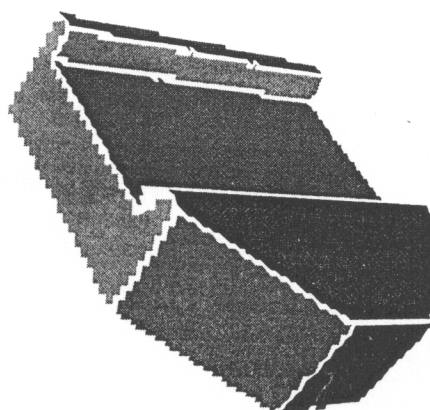
c)



d)



e)



f)

Figure 3: a) original image b) regions of seed descriptions c) regions of descriptions after 1st selection d) regions of descriptions after 2nd selection e) regions of descriptions after 3rd selection f) regions of final descriptions - final results (the image was kindly provided by the Center for Machine Perception from Technical University of Prague)